POSITION PAPER

Urban Drainage - Out-of-sight-out-of-mind?

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1 URBAN DRAINAGE – HISTORY

Provision of safe drinking water, flood protection, drainage and sanitation rank highly among the needs of all societies. Since early civilisation, various means have been used to provide these essential services. Some of the earliest urban drainage structures were built about 5000 years ago in the time of the Mesopotamian Empire (Wolfe, 2000). In subsequent history, many of these structures and associated systems were abandoned, but their remnants can still be found in various places around the world.

Sanitation practices deteriorated after the decline of the Roman Empire, and surface drains and streets were used as the only means of conveyance and disposal of all kinds of water-borne wastes. It was at this time that the "combined" sewer was born. The natural streams and ditches in cities were used to transport all of the water-borne wastes, so that both stormwater and foul sewage were indiscriminately mixed. Rapidly, these "streams" became so noxious that they had to be covered over and turned into sewers. Notwithstanding the apparent lack of any systematic approach to control pollution at that time, many interesting strategies for managing both wastewater and stormwater emerged. In fact, these effluents were not considered as "waste", but rather as valuable resources (Maneglier, 1991). For example, the harvesting of faeces for the production of organic fertilisers (called "poudrette" in France) was in high demand in Paris until the end of the 18th century, and the "Grand voyer" in charge of these activities was very rich and influential. By infiltrating urine into urban soils, saltpetre was formed and used to make gunpowder and for other purposes. Stormwater was collected and stored in cisterns, and constituted an important water supply resource, especially in southern Europe. Unfortunately the various approaches used at that time for wastewater disposal were not hygienic and numerous epidemics of typhoid and cholera in Europe and the United States, particularly between the 1830s and 1870s, prompted city governments to find other solutions for dealing with sewage disposal and eventually its treatment (Wolfe, 2000).

Three arguments proved to be decisive in the choice of the "all to the sewer" solution we still enjoy today :

- A "scientific" one based on an analogy between the human body and the urban settlement ; if the lack of blood circulation in a limb made it sick, the same principle would apply to the lack of water circulation in a part of the city. So, the continuous flow of water appeared to be a necessary, and tanks and cisterns became two examples of "pestilential stagnation".
- A political argument, particularly strong in France after the Revolution, which was based on the notion of equality : all citizens must be equal and treated equally by state and municipal administrators. A common network for collection of wastewater constituted the best solution providing equality of disposal and treatment.
- An economic argument ; in the upswing phase of rapid industrial development it was highly undesirable to allow wide-spread diseases to paralyse production, trade and consumption of products.

At the end of the nineteenth century significant progress was achieved in urban surface water drainage, with the development of empirical design methods for sizing drainage pipes. Intuitive reasoning about conversion of rainfall into runoff led to the development of the rational method, which is generally credited to Mulvaney (Ireland, 1851). In subsequent years, many variations of this fundamental formula have been developed and applied around the world. Essentially the method holds that the rate of flow (runoff) from a surface exposed to rainfall may be calculated from the product of the rainfall intensity and the surface area, with a reduction for the loss of water due to cracks, puddles, soaking into the surface and evaporation. This reduction factor is called a runoff coefficient.

Thus, by the mid 19th century, engineers possessed various concepts and a number of key design methods for wastewater disposal systems, and for the next 100 years or so, these were the tools used in urban drainage design throughout the world. The key paradigm was that stormwater and other wastewater should be collected in urban areas and disposed outside of the urban environment as quickly and as completely as possible. This development was spurred by the linkage of a cholera epidemic to poor sanitation conditions in London by Dr John Snow in the 1850s, following the two Paris cholera epidemics of 1832 and 1848. At that time a number of innovations were introduced attempting to ensure that the solids collected in the drains and sewers of London were *"conveyed most cheaply and innoxiously to any distance out of towns"* (Chadwick, 1842).

The rational method approach dominated engineering drainage practice until the late 1960s, and it is still widely used for certain applications (i.e., small drainage areas with simple tree-branch-type sewer systems, no controls, no storage, no backing-up of flow, etc.). Since the 1960s, rapid developments have occurred in urban drainage practice and this can be linked directly with the invention of the computer. First, a number of runoff computation methods were developed, which advanced the simple "rational method", which provides an estimate of the maximum rate of flow, to hydrograph methods, which account for the actual variations in runoff flow as rainfall intensity changes during a storm. Currently, it is possible to calculate flows in networks of drains and sewers with the precision and resolution needed for cost-effective design, analysis and operation of such drainage systems.

Whilst these advances helped cope with flooding in towns and improved the health of their citizens, the progress in water quality considerations, particularly those addressing the impacts of increasing human populations and their activities on the environment, occurred somewhat later. Initially, the research interests focused on the pollutants transported by stormwater, and by overflows from the relief "valves" in combined sewers in wet weather. Considerable advances have been made in understanding the changes that occur in the quality of drainage waters during transport, storage and treatment, and their impacts on receiving waters. Unfortunately the processes that control water quality in drainage systems are much more complex and less deterministic than those which control the flow rates. Hence many challenges remain in developing full understanding of drainage quality processes. However, the current state of knowledge has enabled to develop a variety of computer based models, which after calibration against field data, are generally adequate for most engineering tasks.

More recently, major changes in drainage design and operation philosophy have been introduced, as a result of : (a) introduction of the sustainable development concept, (b) acceptance of the ecological system approach to environmental and water resources management, (c) improved understanding of drainage effects on receiving waters, (d) acceptance of the need to consider urban drainage, wastewater systems, and receiving waters in an integrated manner, (e) continuing development of computer power and an associated range of new analytical techniques, and most lately in Europe, (f) the concept of ecological integrity in a catchment-wide framework where the urban conglomerations are only one component, yet an important one (Marsalek *et al*, 1993), (WFD, 2001).

A common thread in dealing with "wastewater" in the industrialised world is the separation of the "problem" from the community. Both stormwater and domestic and industrial wastes are conveniently removed effectively and efficiently, and once they disappear "down the hole", the general public has little idea, or interest in, where they go next. It is fortunate for much of the population in the industrial nations that their forebears invested so heavily in the construction of robust and long-lasting drainage systems. These have outlived the needs of the generations that paid the taxes to build and operate them and continue to provide services requiring minimal, though increasing, re-investment. This contrasts starkly with the experience of almost two-thirds of the world's population, who have no such inherited infrastructure, and many of whom struggle with recurrent flooding and the daily need to find a place to carry out the most fundamental personal ablutions.

How can then the needs of the majority of the world's population be recognised and dealt with effectively ? Are the techniques and paradigms, on which the wastewater disposal was based in the past, still relevant today? Not according to Habitat, who believe that *"the systems used in the developed world are not the most effective, efficient or indeed very logical"*, and they are certainly not sustainable (Argue, 1995), (Marsalek & Chocat, 2001). Thus we need to find new ways of dealing with wastewater and the time has come to develop new paradigms (Bacon, 1997), (Ellis, 1995), (Fujita, 1998), Malmqvist, 1999). Communities in developed countries will no longer be able to derogate responsibility for wastewater "disposal" and part of the new paradigm must include the recognition that "waste" water is in fact "resource" water (Otterpohl *et al.*, 1997), (Rauch *et al.*, 1998).

2 CURRENT STATE : WHERE ARE WE NOW?

2.1 Context

Even though this paper focuses on urban drainage, it is difficult to discuss drainage without placing it in a proper context of urban water services, infrastructures and physical, social and political settings. Urban drainage comprises all surfaces and drainage elements (gutters, channels, pipes, stormwater management facilities, including ponds, infiltration structures, etc.), which collect and transport rainwater and dry deposition containing many chemicals, and in some cases even represent sources of pollutants (e.g. urban soil erosion, attrition and corrosion of urban surfaces). In that sense, drainage professionals are responsible for solutions approaching the state of sustainability, but without full control over chemical and material inputs into the drainage system. This dilemma can be documented by the case of heavy metals in urban stormwater ; some of these constituents (particularly copper, lead and zinc) contribute to toxicity of stormwater and particularly road runoff. The main source of such metals is traffic and its by-products. To mitigate such effects, various techniques referred to as "sustainable" urban drainage practices or best management practices (BMP) are applied in drainage design. They include swales, ponds, constructed wetlands and infiltration facilities. However, none of these measures "removes" these metals from the environment; they just immobilise metals in various environmental compartments (soils, sediment, groundwater, or surface water). The only truly "sustainable" solution is eliminating or greatly reducing these materials at the source, as was done, for example, in the case of phasing out lead from gasoline. However, solutions of this nature are beyond the control of drainage engineers. Thus, it may be inappropriate or even naïve to speak of "sustainable drainage" without developing first the concept of sustainable cities.

With respect to water services, urban drainage has a somewhat limited impact on human health and consequently does not attract as much attention as drinking water and its sources and treatment. This is obvious with respect to financing and rehabilitation of urban infrastructure, where drainage seems to be chronically underfunded. This situation will get worse in the future, as sewers and other stormwater management facilities (ponds, wetlands) age and will require major maintenance and rehabilitation (Herz, 1998). It is unlikely that they will attract enough attention to be highly ranked in competition for funding resources.

2.2 Remaining problems

The major objectives for urban drainage remain public hygiene, flood protection and environmental protection. In developed countries, the first two objectives have been more or less accomplished. However, at present, so much emphasis is placed on pollution control to protect the environment that the first two objectives are almost forgotten. In developing countries, hygiene and flood protection are still the major issues, together with the provision of sufficient and safe water supply. Worldwide, only about 15% of wastewater is treated. Many historical problems remain, and new ones continue to arise, depending on the local urban geography and population expectations (Ellis & Marsalek, 1996), (Niemczynovicz, 1999). These problems are associated with :

- Increasing quantities of water draining from impervious surfaces in towns and cities (surface runoff). Typical examples of effects include increased volumes of flow, faster arriving and higher peak flows, causing environmental and property damage, and more and more frequently the loss of life ; decreased low flows in rivers ; depressed groundwater levels, leading to subsidence of urban land and structural damage ; and channel erosion in some reaches and sedimentation in others damaging habitats in urban streams. Some of these problems may become worse in the future as the climate changes.
- The deteriorating quality of water drained from urban areas. Urban stormwater is one of the most sources of pollutants, including trace organics, heavy metals, nutrients (particularly phosphorus), contaminated sediments, and pathogens. This "diffuse" pollution is difficult to quantify and control, and often contributes to the long-term chronic degradation of the rivers, lakes and reservoirs, into which these drainage systems discharge (USEPA, 1994).
- Landscape aesthetics, ecology and beneficial uses. Flows from conventional drainage systems compromise the biological integrity of receiving water bodies, and particularly the abundance and diversity of flora and fauna. They also impair beneficial uses of receiving waters, such as potable water supply, bathing, fishing, general amenity and the aesthetic quality of receiving waters, as well as the recreational potential of the aquatic and surrounding urban landscape.
- Operation of existing urban wastewater systems. Examples include impaired performance of wastewater treatment plants resulting from rapid changes in the inflows of stormwater and the continuing introduction of new synthetic organic compounds, which enter the drainage system, often because there are no controls on what the public disposes into their sinks and toilets ; constraints on urban growth caused by inadequate drainage infrastructure, and ageing sewer systems requiring costly rehabilitation.

These challenges have recently prompted the development of research to devise sustainable strategies for urban stormwater management and new alternatives to the historic legacy of providing one single solution to the urban drainage problem (i.e. combined sewers for all runoff and wastewater). Obviously, a simple solution, advocated more recently, to separate sanitary sewage and stormwater collection, is far too simplistic. At great expense (two networks !) we would still have to deal with all the pollutants found in sewage and stormwater. Thus, we need new strategies for more effective and efficient urban drainage systems that will be appropriate for developing countries, where their implementation will be quicker and less costly than would be the case if they were to adopt the costly, unsustainable and illogical systems inherited by the current population in the developed world. At the beginning of the 21st century, urban drainage has become much more than a simple transport of stormwater out of the city, and the time is right for new paradigms.

2.3 Research needs and emerging issues

It can be considered that urban drainage specialists organised themselves as a scientific community in 1978 during the first International Conference on Urban Storm Drainage that was held in Southampton. Since this date, an International committee has been created under the double sponsorship of the International water Association (IWA) and the International Association for Hydraulic Research (IAHR) (Joint Committee on Urban Drainage). Many conferences have been organised and the current knowledge begin to be collected in specific books (Chocat *et al.*, 1997), (Ellis *et al*, 2002). Yet many research questions remain without any correct answer. One of the most open questions concerns the construction of the new strategies that are needed to implement a more sustainable urban drainage.

Two studies, carried on in the late 1990th in USA (Fields *et al.*, 1998) and in Europe (Chocat *et al.*, 1999), identified four key areas, in which advances were needed :

- alternative technologies for stormwater management (structural best management practices, BMP),
- innovative strategies for stormwater management (including non-structural management measures),
- treatment of urban wet-weather discharges, and
- tools for the analysis of drainage system operation.

First, it should be noted that the development of new strategies or technologies is strongly impeded by economic problems (costs, financing), institutional (the form of water management corporate structure in a country, changes in mandate and responsibilities), sociological problems (acceptance by the public), urban planning challenges (integration into the landscape, cooperation between the wastewater department staff and others involved), problems with policies, regulations, and regulatory regimes, etc.

From a technical point of view, three levels of problems must be overcome :

- <u>First level problems</u> concern the lack of knowledge of the impacts and combinations of impacts associated with different contaminants in urban runoff (nutrients, heavy metals, trace organic toxicants, pathogens, etc.) and of their interference with the receiving environment and its beneficial uses.
- <u>Second level problems</u> concern the uncertainty of impact assessment (in terms of modelling and measurement), particularly with respect to long-term cumulative impacts.
- <u>Third level problems</u> concern the use of better information for decision-making ; e.g., what is the best way of considering the environmental/ecological impacts in the planning, design and implementation of works for controlling stormwater discharges.

Specific challenges in urban drainage research arise from the system complexity, both in physical and institutional terms, and are particularly important when deciding whether the innovative drainage technology should be applied on the catchment surface, where it interferes with numerous other uses, rather than remaining below surface.

Emerging issues in stormwater management (SWM) include introductions of new chemicals posing water quality threats (e.g. endocrine disrupters), continuing accumulation of contaminated sediments in BMPs and receiving waters with the associated cumulative impacts, and concerns about potential climate change (precipitation changes ; higher air temperatures, rising sea level, different water quality process rates, migration of disease vectors). Among the engineering problems, challenges of ageing infrastructures and their deteriorating performance are increasingly recognised and call for new planning methods to invest the limited available funds in such a way that the right pipe is rehabilitated in the right time with the right method.

From the institutional point of view there is an ongoing change in the ownership and operation of the SWM systems. While traditionally the drainage systems were publicly owned and operated, there is a trend towards other modes of ownership and operation, involving the private sector. Towards this end, stormwater utility companies (both public and private) are being set up to provide SWM services. Typically, these stormwater facilities operate within large companies, which can provide integrated services to urban populations, but whose primary mission is to make money and reinvest profits anywhere, including outside of water economy.

3 POSSIBLE FUTURES

There is a proverb which is often quoted, even though its source is rather unclear : "*Prediction is a difficult art, especially when it deals with the future*". Yet, we take the risk and try to imagine the future development in our field.

As it is often the case, major incidents and unforeseeable changes in political preferences determine the "grand route" of the future development, and to cover various odds, we present four different scenarios instead of one single "most likely" future. All four scenarios seem rather pessimistic, and three of them reflect our concern against "simple solutions" and radical changes, while the last one demonstrates that the current development must not continue.

Perhaps this pessimism is partly caused by the fact that we do not have sufficient control over drainage systems with respect to land use and chemical inputs, and the level of importance and funding allocated to drainage by the society.

Yet, the scientific community ought to use its professional knowledge to guide the development of urban water management into a future that is enjoyable for our children and sustainable for their environment. A description of such a future scenario concludes this paper.

3.1 The green scenario

The first possibility is what we call "the green scenario". It is illustrated by the hypothetical keynote address delivered by a hypothetical Prof. W. Pound (see box 1). In that scenario, defenders of "BMP's", "SUD's", "LIDS" and other "alternative techniques" have won the game. While in some jurisdictions or countries this scenario might be referred to as a new paradigm for stormwater drainage (see e.g., proceedings of the INTERURBA II), its essential principles were formulated in the mid 1970s and implemented in the Woodlands, Texas Planned Community (USEPA, 1979). In this newly developed community, drainage was designed to preserve natural drainage as much as possible, by protecting and enhancing natural infiltration areas, conveying runoff in open channels (vegetated swales) and balancing runoff flow rates by passage through in impoundments. Runoff was further reduced by the use of porous pavements. Since the completion of the Woodlands (pop. 150,000), other communities in the USA (e.g., Bellevue, pop. 100,000) and elsewhere have also adopted these approaches, though typically in new developments, or in upstream areas of the existing developments.

These examples cover just one aspect of urban water, surface drainage and its impacts on receiving waters. At the same time, new understandings are beginning to emerge on the relationships between system-wide uses of BMPs and how they may mitigate the effects of urbanization on the receiving nature's waters (Urbonas and Jones, 2001). More work needs to be done with respect to stormwater impacts and wastewater reuse and recycling, and the integration of all urban water cycle components utilizing and discharging into nature's waters. Such an approach has been formulated by Lawrence *et al.* (1999) as "total urban water cycle based management", which encompasses: (a) reuse of reclaimed wastewater (for pollution prevention, sub-potable water supply), (b) integrated stormwater, groundwater, water supply and wastewater based management (water supply, flow management, water and landscape provision, substitute of sub-potable water sources, and protection of downstream areas against urban impacts), and (c) water conservation based approaches (efficient water use, reduced water demand for landscape irrigation, and substitute industrial processes with reduced water demand). This type of management can be achieved only with decentralised solutions applied everywhere (Harremoes, 2001). There is some experience with decentralised measures in stormwater control in the form of small on-site measures (lot grading, drainage swales, roof runoff restrictors, etc.). Continuous operation of such measures cannot be guaranteed, without frequent and costly inspections. With respect to wastewater, deficient operation and maintenance of on-site measures and facilities would create public health hazards and as such represent the greatest impediment to a greater acceptance of this approach.

3.1.1 Main characteristics of the green scenario

Ecologists are in charge. They have imposed a so-called "balanced integrated approach" attempting to combine both "soft" and "hard" technology in achieving sustainability of urban drainage. This scenario may be hard to imagine, because in western societies, only the engineers have licences and the ultimate responsibility to build infrastructures. Soft measures include source controls (both, legislated and voluntary). The key words are :

- Sustainability ;
- Environmental concern ;
- Back to nature ;
- Source control techniques and infiltration systems ;
- "Green cities" ;
- "Cleaning the future" vision ;
- Engineering "married" with social sciences ;
- Water supply with different water qualities
- Separation of blue, grey, black and yellow wastewater
- Recycling of, both, waste water and waste in small local cycles (house, lot, neighbourhood)
- Water harvesting.

In such a scenario, responsibility is decentralised. Long-term master plans for large-scale infrastructure disappear. Many ideas, devices and systems are available, and numerous small companies offer a wide range of technical and operational services.

3.1.2 Risks and problems of the green scenario

This scenario is dangerous for at least three major reasons. The first one is that we are not sure how harmless the promoted alternative solutions really are and their potential effects may be of cumulative and long-term nature, thus taking long time to manifest themselves. The hope of "no impact development" is not reasonable (Strecker, 2001). Urbanisation does produce impacts on the land, on the soil, on receiving water and local microclimate. These impacts can be low if the infrastructure presence is small, and the quantity of water used and pollutants generated are limited, but they do still exist. It is not clear whether nature alone can cope with these impacts; some pollutants (e.g., heavy metals or some trace organic toxicants) are persistent. Once they are in the ground or attached to bottom sediment in ponds and streams, they will stay there, accumulate and, under unfavourable bio-chemical conditions, enter the food chain or are released into the environment. Water detention can mitigate the risk of flooding downstream, but the water balance and sediment transport regime will always be different after urbanisation.

The second risk follows from the fact that green solutions are understood by local authorities as a convenient way to free themselves from the costly obligation to maintain their water infrastructure. On-site stormwater facilities would be built and operated under the private property owner's responsibility. This transfer of responsibility to the end-users might result in no or poor maintenance and, consequently, numerous small failures. It could also, more likely, result in the development of new businesses taking care of the problem, which would be now occurring at many locations throughout the urban area. Also lawyers might not be unhappy with this arrangement, because of the increase in lawsuits, in which downstream owners would sue upstream neighbours, because their allegedly improper drainage system flooded the downstream property.

The green scenario is not necessarily sustainable just because it appears more ecological (in a political sense). Its sustainability needs serious studies, particularly with respect to the long-term behaviour of decentralised facilities and the feasibility of managing these facilities in the long run (ASCE, 1998). There is a clear risk underlined by Mikkelsen (2001) that we create a garbage dump in each garden and re-create a situation that Europe struggled with to overcome in the 1960s when many illic it dump sites were finally closed down. The wide-spread distribution of small pollutant deposits could be a good solution to preserve the quality of the "nature", but it also might create health hazards that are unknown today.

Generally speaking, the system objectives and performance criteria of the green scenario are poorly defined. Essentially, it is thought to support sustainability, but without knowing how sustainable or to being sustainable it gets. We are faced with appealing principles, ideas and visions, but practical experiences in terms of success and failures, and cost-efficiency are unclear.

The last, but not least, problem is that the way to proceed from the existing centralised systems to future decentralised systems is not obvious. The existing urban water systems are enormous infrastructures that took decades to build. Decentralised solutions also require large investments, and their wide-scale implementation would stretch over similar time spans. Thus, two functioning systems would have to be financed over a long period of time (at least one generation). During this period, fewer and fewer people would contribute to pay maintaining the old system that would obviously become increasingly obsolete. When finally the centralised systems would become useless and could be turned off, the resulting write-off of (financial) capital would be unprecedented in times of peace.

3.1.3 Reasons why this scenario could happen

Why might this scenario become a reality ? We believe that the main driving forces towards the green scenario are its positive political appeal and the fact that it is economically appealing (at least in a short run) for those public utilities that struggle financially.

Its objectives are undisputed, both internationally and locally (e.g. Brundtland commission, local Agenda 21). It receives "green political support", particularly in rich countries where people have bad consciousness over exploitation of nature and want "to do something good", and it is defended by a lot of enthusiastic "experts". From the sociological point of view, it appeals to well educated well-to-do part of the society, often living in up-scale developments or eco-villages.

Eco-radicalism was strong during the last two decades. Many people are critical against technocratic solutions that they do not understand. The "small is beautiful" principle is often advocated ; and alternative solutions seem attractive while there are doubts whether the present system can be regarded as sustainable. Thus, although radical, the green scenario is not impossible.

3.2 The technocratic scenario

The technocratic scenario differs much from the green scenario. It is illustrated by the hypothetical concluding speech at the 17th International Conference on Urban Drainage (ICUD, see box 2). Publicly employed engineers are in charge and decide upon both, the technical approaches and the way the systems are managed. This scenario represents the classical approach, before privatisation became an international issue.

3.2.1 Main characteristics of the technocratic scenario

The engineers in charge appreciate that society has delegated an important task to them. By applying the proven technology, coupled with redundancy and large safety factors, they make sure that the system does not fail. The solutions are not necessarily cheap, but they are robust and impressive from a technological point of view. Thus, this scenario is basically conservative, even if ambitious engineers might get a chance to apply advanced technologies to water systems, e.g. :

- Automation, control, robotics ;
- Real-time operation ;
- Third generation of communication - computer, use of mobiles phones ;
- Use of biotechnology for water quality control ;
- New field measurement and laboratory equipment.

This system will be designed with sufficient numbers of fail-safe devices and fall-back alternatives, so that operational risks are kept small. Cost-benefit is one of the considerations, but not the most important one, and if in doubt, the technologically better solution is adopted, even if it is more expensive. This approach focuses strictly on good technology, i.e. solutions that an engineer is proud of. Drainage systems rely almost entirely on end-of-pipe solutions as well as some (technocratic) source control measures (e.g., harvesting stormwater from roofs for gardens irrigation). The development of new water saving devices in household and industry and water recycling solutions in water scarce regions is managed by large companies and strictly supervised by central authorities (minimise recycling to minimise risks).

Long-term planning ("Grand Master Plan") is the rule to ensure best technical quality ("the pride of the engineer"). Maintenance and renewal of central systems with large size and with redundant components is the top priority. Responsibility for system operation and maintenance is centralised and mostly public. Water service remains to be a monopoly with no competition over services or approaches.

3.2.2 Risks and problems of the technocratic scenario

We certainly have the technology to solve urban water management problems in a "technocratic" way. We can build huge sewer networks and use modern technologies, such as real time control, to protect cities against flooding, with some acceptable level of risk. We can build and manage end-of-pipe treatment plants capable of purifying wet-weather effluents with a very high level of performance. We know how to rehabilitate streams in order to produce clean and valuable places for the public. But ...

The first problem is financial. Such solutions are expensive, and if implemented in top engineering quality, they are very expensive. There might not be sufficient political support and then this scenario gradually slides towards the "privatisation" scenario (see below). Public utilities might need to join large companies, or risk being taken over by them, because private companies do not require political support for raising capital and making investments. In developed countries, it is likely that funding could be found for this scenario. People accept to pay more than 200 € a month for phone, TV and internet connections. It is reasonable to believe that people will accept to pay more for clean water, which is much more essential to their life, especially if they think that they have no other choice. The text in the box that illustrates the technocratic scenario shows that the possibility of this scenario prevailing is not unrealistic.

However, due to the lack of funds, lack of engineering expertise, or operation and maintenance capacities, the technocratic solution is totally impossible to implement in developing countries. If this scenario would be the only way to provide urban water services, we would exclude 4/5 of the world population from access to clean water and from a minimum protection against flooding and public health hazards.

The second problem is that nature is not easy to harness. Whatever level of protection is chosen, one has to accept that a rainfall greater than the design storm can occur. In that case, consequences could be very dramatic. In other words, technological perfectionism will avoid all but the most extreme problems, leaving people mentally unprepared for such rare, but terrible catastrophes.

3.2.3 Reasons why this scenario could happen

The technocratic scenario offers intellectual challenge and research opportunities - the classical incentives for engineers and scientists. The engineering community can argue that "robust" solutions (e.g. sewage storage tunnels in downtown areas) offer guaranteed performance and meet environmental protection goals, so the engineers in charge will be politically supported as long as the system functionality is guaranteed, service is provided, and money is not openly wasted.

The approach fits well into our present developed world, and profits slowly but surely from fast development in related fields. There seems to be a synergy potential (microbiology, gene manipulation, computers, nano-technologies, etc.) that might be used in the future. Why should we apply "stone age" methods in urban water systems when modern technology, carefully and conservatively applied, solves the problem ? In fact, is it not appealing to politicians, government and decision makers to show that we are in line with technological progress - the latest, the most powerful, the newest control devices - to ensure an equally good service to all citizens?

The scenario assumes that it is unrealistic to expect essential changes in individual and corporate behaviour with respect to the environmental protection, or at least that such expectations are not needed. Thus, urban water management is relatively easy, since it operates largely independently of the political context.

Lastly, but not the least, the scenario assumes (and even requires) that most urban dwellers are not really interested in the details of urban water management, and politicians exercise low level of control as long as there is no trouble.

3.3 The privatisation scenario

The privatisation scenario might be a consequence of the situation, in which the credibility of the technocratic solution was undermined by repeated failures, obvious waste of money, or chronic under-funding. An urban water system can only be privatised once, but it is very tempting for politicians : Privatise water infrastructure, sell the assets and use the money "to do something good" for the people. This idea becomes particularly attractive where ageing infrastructure requires large investments and public agencies wish to avoid the need to raise such funds (by raising taxes) in public debate and with elections coming up.

Obviously, the leading idea of the privatisation scenario is not to find the most beautiful solution to a technical problem, but to make money, i.e. provide a system with sufficient technical quality to deliver the service, but no more than that. In the worst and not unlikely situation, the water company might define the level of service itself (because it holds all the expertise), pursuing its own objectives and using a proper marketing approach.

3.3.1 Main characteristics of the privatisation scenario

Investors and economists are in charge, and the buzzword is cost-efficiency. This is achieved by control of labour costs and limited investments into infrastructure. When funding shortfalls loom (i.e. economic losses), the private company will insist on increased service fees and/or re-negotiation of the original contract (it might even be formulated with this eventuality in mind). Sustainability of the approach is an issue, but only as long as the economical sustainability of the company is not at stake. As economic issues play the major role, the functionality of the system as well as ecological issues are just standards that have to be complied with at minimum effort. Key words are :

- Efficiency and effectiveness ;
- The "true" value of water.

The technological solutions will consist of "reasonably maintained" centralised systems with "decentralised pockets" (where profitable). Such a system is easier to manage, and the service charges are easier to invoice. Due to the physical nature of the system very few, but huge private companies have total regional monopolies. Competition only happens once, i.e. when the getting the initial contract is at stake. Without extremely competent and politically strong regulation this kind approach is bound to result in increasing service fees. How far environmental concerns will be taken seriously remains to be seen ; regulatory pressure might push the issue, but carefully worded contracts will be a necessity in any case.

3.3.2 Risks and problems of the privatisation scenario

The main risk is that the price for water service will become unreasonable, especially for developing countries. Market concentration could be enormous : only few companies could manage the water resources on the planet. Water could assume the same role as energy today : being no longer a natural resource (like the air we breathe) but a tradable commodity such as crude oil (Bryce, 2001).

The dilemma of water service companies is that regulators want to keep the fees down while investors require revenues and profits, which may be reinvested in other fields totally unrelated to water. A solution to the dilemma could be to offer "new" but deteriorated services to cut costs (e.g. bottled water in exchange of lower quality tap water).

Private companies might walk away from operating contracts, accompanied by legal disputes when encountering significant financial difficulties. They even might get bankrupt and stop operating over night.

Another risk is that companies could develop short-term strategies guaranteeing returns on investment, but disregarding long-term sustainability issues.

Employees might become frustrated by being denied the opportunity of doing their job properly and not being acknowledge for doing good job. Mergers and take-overs, accompanied by re-organisation, will frequently lead to changes of staff, or changes of tasks that the staff perform. The experienced engineer, knowing his system in-and-out for decades, will become a relic of the past.

3.3.3 Reasons why this scenario could happen

Four major driving forces can make this scenario happen :

- Selling public water infrastructure creates large one-time income that can be used for many "good purposes" ;
- Everybody needs urban water services ; given a "well-formulated" contract water service can be a profitable business ;
- Actual (or perceived) failures of the technocratic approach will support the opinion that "private is better than public" ;
- If privatisation is one of several options, private industry will attract the best engineers and offer them opportunities and resources to develop their creativity and their innovation capacities. Thus, the competing public utilities will encounter a steady brain drain.

For private companies it is tempting to gain a business monopoly. At the same time, politicians have an opportunity to shed responsibility for under-funded, ageing water infrastructure and the need to raise capital, deal with municipal employee unions, public complaints about poor service, increases in fees, etc..

Nowadays, almost everywhere in the world (European Union, South America, even in some countries in Africa) we see a clear promotion of privatisation presented as the (only) strategy to "make systems work". When trying to penetrate the market, the private water companies show some generosity towards researchers and international bodies by awarding them financial grants. Shareholder value principle and the current development in many countries promote this development. It benefits from liberal political support of the argument that customer costs will become lower because of the greater economic efficiency of the private sector. Looking at current trends, this scenario might be the most likely to become our future reality.

Last but not the least, this scenario is somehow auto-engaging. Once it has reached a certain level of development and acceptance, it is difficult to change the strategy. The master of water resources and water utilities ultimately becomes the master of the game.

3.4 The business-as-usual scenario

The forth scenario is probably the most likely development, simply because is represents the current status of urban water management ; we will continue as we have done for the past 30 years, without any clear strategy or political vision. This scenario is illustrated by the letter from Lisbon (Box 4).

3.4.1 Main characteristics of this scenario

Nobody is in charge. This scenario is poorly defined, because the current level of drainage services / approaches widely varies between countries and between jurisdictions. Practically everywhere, it is recognised as (or called) "not sustainable", yet it is the most common.

Its main characteristics are :

- Mixture of the green, technocratic and privatisation scenarios ;
- Lack of clearly formulated objectives and aspirations ;
- No rational discussion about acceptable risks and opportunities ;
- "Yes, large investments are necessary - but not now" ;
- "It is only family silver, we can sell it and do something good with it" ;
- Expertise disappears towards other sectors ;

- Small investment into R&D, and hesitation to apply innovative approaches.

Stumbling between the technocratic tradition and green ideas, the pathway is unclear and the goals are fuzzy, and developments remain localised. However, the most pressing problems are attacked, just because it is necessary. Master plans are tried to be implemented, but with frequent political interventions after incidents and accidents. In case of problems, "quick-and-dirty" solutions are implemented, exercising activism and giving way to political pressure. All but the largest utilities experience a brain drain, and their lack of competence results in simplistic solutions of the type "one-size-fits-all". The overall result is a gradually decreasing quality of systems and services, and operation in a reactive mode.

On the other hand, it is the scenario that incorporates most approaches to urban water management that one can think of. In a Darwinist style, through this competition of approaches and survival of the fittest, i.e. through mutation, recombination and selection, an optimal approach to urban water management might evolve. This eventuality would require a number of prerequisites, including proper information and data, non-dogmatic discussions, sufficient public interest and the availability of enough time (i.e. slow urbanisation) for such a process.

In fact, there are hardly any countries where all these prerequisites exist.

3.4.2 Risks and problems of this scenario

Refusing to make a choice is obviously a dangerous idea, resulting in accumulation of disadvantages of the three first scenarios, without being able to understand why things are getting worse.

In the developed world this situation is further disguised by a rather low risk of acute (catastrophic) failure, because water systems usually work reasonably well and service deterioration is so slow that it goes unnoticed. However, larger problems are already being experienced in regions suffering from water scarcity.

Other problems emerge from poorly defined performance objectives and lack of clear-cut priorities. Practical solutions require frequent changes between approaches that are neither consistent nor continuing, and therefore unsustainable. Operations are under-funded and have to rely on general budget allocations and subsidies from senior levels of government, while the costs are high due to the necessity to manage different systems that are tried out in parallel. Finding money is more and more difficult, particularly when social and environmental concerns about water services decrease and professional marketing is lacking. Public urban water utilities find themselves squeezed between quarrelling pressure groups, that do not even acknowledge basic achievements, and the private industry that is eagerly waiting to take over. Or is there any other product in the world whose "brand name" variety costs 1000 times more than its "no name" equivalent (i.e. bottled versus tap water)?

Risks and acute problems of this scenario might not be so severe for the developed world, but they are unbearable for developing countries, where neither inherited infrastructure, nor money, nor experienced engineers are available. Again, the outlook for the developing world is particularly dull, and with business-as-usual the gap will increase quickly and endlessly between rich and poor countries.

3.4.3 Reasons why this scenario could happen

The most important reason is the resistance against change, visible as the inertia of technical, administrative, and political systems. Stated positively, in the absence of acute problems (catastrophes), the incentive for change is low. In fact, in most jurisdictions urban water services operate without dramatic failures and thus, attract limited attention of the public and politicians.

3.5 Conclusion

Is the future of urban water necessarily so gloomy? Not at least from a theoretical point of view, solutions do exist. We need to change our level of comprehension and to use a holistic approach. This hope is developed in the next scenario.

4 DREAM FUTURE

There are good reasons for "hydro-optimism" (Stockholm International Water Institute, 2001). Increasing water scarcity due to an increasing world population and equitable provision for all, is raising the importance of water, not only as a fundamental human right, but also as a cornerstone for economic, health and food security. Three areas that need to be tackled to respond to current shortages and future needs are: Institutional systems, technological advances and individual responsibility. Water could become a catalyst for greater world-wide co-operation, rather than a source of conflict (Asmal, 2001). In the preceding part of the paper four different more or less likely scenarios have been presented, none of them being particularly appealing. Thus, the temptation is to develop a vision of utopia, where society is full of wisdom, solutions are found by working together, resources are valued, and nature respected. Such a vision is appealing, but its further analysis is likely to be a waste of time for both, the authors and the audience. Instead, we should ask ourselves what could be the optimal, yet realistic future of urban water management.

First of all, it must be clear that the vision of a coherent world-wide water policy is utopian at the moment and will be so for decades, despite initiatives such as the proposal for a world-wide Water Innovation Fund (Serageldin, 2001) and an International Water Centre (Swaminathan, 2001). Industrialised nations do have fully functional systems, whereas in developing and emerging countries this is not the case. Developed world technologies cannot be installed in developing countries in the future due to their high cost. Therefore, as any changes in these alternative system types will have to start from different baselines, a single unified world-wide strategy is unlikely to be achievable. Instead "adapted solutions" have to be sought that take into account the characteristics of the individual situation.

The optimum scenario in the industrialised world is probably some combination of the beneficial properties of the scenarios discussed earlier. However, key aspects of existing systems will remain in existence in the near future – at least in the densely populated areas. These systems have to be adapted with "green" solutions wherever appropriate and with strong incentives to adopt novel solutions. In review of the last Stockholm Water Symposium (2001), the key steps toward greater water security were listed as:

- More flexible institutional arrangements ; and,
- Increased water awareness among all stakeholder groups.

These were seen as more important than scientific and technological changes. The importance of ensuring that water professionals were competent, multidisciplinary and up-to-date was emphasised and seen as a mission opportunity for the proposed International Water Centre. There was even a need identified that some experts in the water area should "de-learn" so that they would have a broader vision than they have now, as to what would be acceptable and appropriate solutions. The globalisation of economic systems was also seen as a potential impediment with consequential institutional arrangements constraining innovation and the need to introduce more appropriate "local" solutions.

As far as urban drainage systems are concerned, there is agreement that both, storm and sanitary "wastewaters" provide a resource opportunity within the Integrated Water Resource Management framework (Ellis, 1995), (Krebs & Larsen, 1997), (Larsen & Gujer, 1997), (Chocat *et al*., 2001), (Marsalek & Chocat, 2001). Thus, our twentieth century paradigm of "waste" water needs to be modified to "opportunity" water.

The cornerstone of a realistic future vision is therefore decentralised wastewater treatment and utilisation at the local level wherever this is practicable. This requires both technological development and greater individual and community responsibility. It may be achieved by a combination of source controls (provided by the industry) and technological development (biotechnology research). By industrial and technological re-engineering of substances used in the household, the liquid waste stream from this source will become of comparable quality to rain runoff (Household Hazardous Waste Forum, 1999). Thus, a major portion of the pollution problem in urban drainage would be solved. By applying infiltration systems for the discharge of the household effluent, a sustainable solution, at least for the dry weather situation, is feasible, provided that groundwater quality is not compromised and groundwater aquifers can accept these extra inputs. The need for integration of these efforts with other measures, i.e., total urban water cycle management, is obvious. Jurisdictions with high domestic water use (in some places, 300 L/capita/day or even more) produce too much wastewater to be treated and infiltrated on site. This can be illustrated by a simple numerical example from Southern Ontario, Canada – in a low density residential area, a family of five living in a single detached dwelling with a lot size of 500 m^2 will use 1.5 m^3 of water daily. Over a one-year period, this represents about 500 m^3 to be disposed, which is equivalent to a depth of 1 m. Such a depth is about the same as annual precipitation. Thus, compared to the natural situation, the rate of recharge would about double and would result in rising groundwater tables. Similar calculations for densely inhabited urban areas would indicate much greater overcharging of local groundwater aquifers.

What remains is the discharge of excess rain runoff. In densely urbanised areas there is usually no way how to get around the traditional pipe system. However, large improvements over conventional systems can be attained (as in Kyoto) by application of ecological engineering as much as possible (water harvesting, infiltration, etc.) and by applying a new generation technology for water routing and runoff treatment.

The key feature of any optimum drainage solution in industrialised areas is the fusion of the existing traditional technology with recent ecological and technological achievements, taking due account of the increased responsibility of the individual and local community. Applying higher technology to decentralised solutions would shift a significant part of the cost (and responsibility) from the public to the individual. It is unlikely that this new system would function without an inspection and enforcement system; why should this field be different from other fields of human behaviour, in which we need laws, regulations, policing and penal systems?

Where feasible, all opportunities for resource recovery should be taken, with water re-use and recycling, and utilisation of nutrients from human wastes. This approach would: (1) create a greater awareness for water in the urban environment, which is largely unknown today, except in certain eco-villages (Hedberg, 1999), and (2) ease a major economic and infrastructure problem of current water supply provision. The existing large pipe infrastructure systems would remain for the foreseeable future, as these would only be used for the transport of a diminishing amount of rain runoff (or household effluent of the same water quality). Hence the pressure to maintain or even expand the serviceability of these large and expensive systems would be significantly reduced.

For such an approach to be viable, it would be necessary to change the current institutional systems, in which the wastewater utility (i.e. the asset owner) is valued according to the infrastructure assets it owns, and the revenue income is based on volumes and pollutants handled. Both "hard" infrastructure and handled wastewater volumes would clearly be reduced under such a scenario. As a consequence, countries like the UK would need to fundamentally review current the institutional systems to ensure that the utilities were not under-valued due to the loss in assets.

Other barriers include professional reluctance to change from the "way-it-has-always-been-done", the QWERTY problem (Geldof, 1999). Evidence of "mono-thinking" and false beliefs is apparent even for water professionals (Biswas, 2001). Thus, new approaches to educating professionals will be needed, and new ways of providing real knowledge about water/wastewater systems will be required for new system "operators" (consumers) at the local level. This will be needed to achieve the "radical shift in thinking" required (Stockholm International Water Institute, 2001).

Optimum approaches to future urban drainage for developing countries will be different from what is envisaged for developed countries, inasmuch as the fusion between existing and new technologies is not likely to be as big an issue. This is both a virtue (no restriction due to existing systems) and a burden (as a functioning asset system does not exist). Megacities in developing countries face essentially the same problem with respect to urban water management as densely populated urban areas in the 1st world: land use. Many communities have to cope with dense overcrowding and no sanitation, and the associated increase in imperviousness, which inhibits the natural water cycle and requires an appropriate disposal of rain runoff. Typically, the developing countries with sanitation and drainage problems also have problems with inadequate water supplies. Note that increases in water supply will further influence local water imbalances.

Here the key principle must be the utilisation of all "wastes" wherever feasible. It is likely that in many cases this may require high technology solutions and the fusion of tradition (pipe systems where necessary), with “green and ecological technologies” (infiltration, ponds, natural waterways, water harvesting) and modern technology (treatment and operation facilities where affordable). The principal consideration will be economic, and it is difficult to see how adequate resources can be made available to achieve what is required within the current globalised economic systems.

Where possible, the approaches adopted must take into account the need for easily repairable technological implementation, increased employment opportunities for local inhabitants, and the provision of basic education. Inherent flexibility and adaptability (key criteria for sustainability) must be built into water/wastewater systems due to the rate of change of circumstances in developing country communities. Greater "consumer" involvement and responsibility for water and wastewater services has been shown to work effectively at the community level in developing countries (Stephenson, 2001), but where sophisticated technologies have to be used, this may be problematic.

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***Box 1: We only wanted the best but achieved the mediocre - A sceptical look back on urban water management in the past decades – a keynote address delivered by Prof. W. Pound at the 25th Annual Meeting of the Association of Retired Urban Water Engineers, January 24-25, 2021, Sunset Resort, Marbella, Spain*.**

Dear colleagues and friends

After three decades of dispute the battle over how to manage urban water and wastes was finally won by the advocates of decentralised water and waste management schemes, more widely known as the "The Greens". The long-lasting discussion, often fundamentalist, only sometimes balanced and constructive, had many outcomes, but one effect was particularly important, namely, the widespread uncertainty whether to pursue traditional centralised or decentralised solutions for urban water management.

You all know the difference : The centralised schemes, on the one hand, are the large networks for, both, water supply and sewage and drainage, with one standard of water quality (the best), 2 or 3 pipes leading into every home, and central purification and treatment plants located way outside of the urban areas. The decentralised systems, on the other hand, are characterised by roof rainwater collection, black, grey and yellow wastewater separation, on-site treatment and recycling, and no pipes whatsoever reaching or leaving the homes.

The uncertainty that I mentioned above led to a situation where both approaches were applied for the past decades in parallel. Some principal court rulings and some municipal governments adopting this seemingly environmentally friendly approach also backed this policy. Thus, all citizens essentially have been financing two urban water and wastewater systems at the same time for many years. You all remember what happened. We had to cut costs everywhere, service fees were frozen, funds dried out and maintenance of the old networks became non-existent.

Major incidents such as the flooding of the London underground after a trunk sewer collapsed, dozens of trapped people in the Berlin Convention Centre for the same reason, and the terrible poisoning of the western Paris water supply main by an unknown terrorist group undermined the credibility of the centralised solutions further. The customers turned away from the water companies that were more and more regarded as big business profit machines rather than "our local waterworks".

Service levels deteriorated even more, and you all know that the days when we all could drink our glass of water from the tap are long gone by. I showed this picture of a toddler reaching out for tap water to my students when I started my career as a university teacher many years ago. They laughed at me and found it trivial and boring. When I show it today I am denounced as an odd science-fiction character. But it simply shows what we all had without recognising it : namely clean water for everybody at an affordable price.

Decentralised systems became the solution, if not the panacea. The guru of decentralisation, R. Beavercreek, persuaded many of us 20 years ago : decentralised systems would require local operators, local responsibility, and local care, and the evils of big business would disappear. Everybody would manage his own water supply and cycle of wastes, if not in the house then in the neighbourhood, at the most. Thus, everybody would become more conscious about the value of water and the resources in wastes, and all would take much more care using them.

You all know how far away we are from this prophecy. In spite of all investments and subsidies for decentralised urban water and waste recycling systems only 50% of the total population has them, usually those who can afford them. The other half is bound to use the old networks that barely function any longer. The sanitary conditions in the low-income areas of our cities are approaching those experienced during the industrial revolution in the 19th century.

But with one respect we are all equal, indeed : We all have to drink bottled water. Whoever invested into this industry 2 decades ago has made a fortune, both, in western economies and in the developing world.

New professions emerged. Hygivisers, i. e. hygiene-advisers, who did not exist 20 years ago. They advise people about the meaning of the blue, green, yellow, red, and black pipes in their households, their in-house waste recyclers, and watch out for early detection of symptoms of copperosis, detergentia, and all the other new and widespread diseases that were unknown until a few years ago. Today the number of hygivisers is larger than the total medical sector.

In 1850 the situation was desperate, and our forefathers made an enormous effort to solve the urban water and sanitation problem. Our situation today is not desperate but miserable. Gradually, we have accepted to pay more and more money for a poorer and poorer service. Unfortunately, we have become used to it and most of us do not even remember that things have been different a generation ago. Yet, nobody would be willing to pay even more money to restore functioning urban water systems and get back to the "good old days" when our tap water was safe and our wastes being taken care of people who knew what they are dealing with.

With this gloomy outlook I like to thank you, my dear colleagues, for your attention. I also want to thank the Association of Retired Urban Water Engineers for paying for my train ticket to attend our annual meeting.

Box 2 : The 17th ICUD is now finished and it is time to draw the main conclusions of this outstanding conference that was held on Maurice Island from September 10 to 18, 2026.

The most important conclusion is that BMPs, or SUDs, or other ESWMs (Ecological Storm water management), which were the dominant paradigm of the first years of the century, have now proved to be totally irrelevant, inefficient and dangerous. Some visionaries, during the t 1990th, already underlined the fact that the result of such measures will be "to put garbage depot in each garden". Recent studies presented during the 17th ICUD showed that this fear was well based. For example Jones & al (2026), after analysing the sediment in 20 ponds throughout the USA (ponds that were between 30 and 40 years old) (study funded by the WWC), found that these sediments were heavily polluted by several heavy metals (Pb, Zn, Cd, Cu) and some organic toxicants. Yamamoto and Kaderate (2026) found very similar results in Japan (study funded by the WWC). Dupont and Dupond (2026) focused their investigation on infiltration facilities in France and some other countries of Western Europe (study funded by the WWC). They discovered that, due to bacteriologic phenomena, heavy metals that were supposed to be trapped in the first layers of the soil were in reality much more mobile than expected and could migrate to the aquifer regardless of the depth of the underlying unsaturated zone. A comparative study of the sustainability of different systems, carried out by Azerty and Qwerty (2026) (study funded by the WWC), concluded without any doubt that end of pipe solutions were the most efficient systems.

Finally, all the participants (except a minority of old ecological activists, for example Ashley (2026) or Philips and Morrison (2026)) agreed on the fact that end of pipe systems were to be developed, or improved, all over the world, since this system is the only one that is really effective. Yet, very different opinions were defended regarding what is the best way to fund the necessary investments.

The total cost for FSCs (Financially Solvent Countries) was estimated between 500 US$ billions (Field, 2026) and 2000 US$ billions (Martin, 2026). A very interesting talk, given by J. J. Money junior (Vice-President of WWC) during the closing sessions, showed that WWC had enough liquidity to be able to build the required facilities in less than 10 years. He suggested that by doubling the cost of the cubic metre of drinking water (that means a mean price of about $200 per cubic metre) would allow obtaining a return on investments in less than 15 years. Generally speaking this cost was found acceptable by most of the participants. However, many of them (Mother et al., 2026 ; Lauri et al., 2026, Schueler, 2026, etc.) emphasised the fact that investments in stormwater management must be funded on the basis of impervious areas and not the water consumption. This point of view was specially based on the fact that the "shortened water cycle" (direct recycling of wastewater to produce drinking water) is being developed in most of FSCs. The defenders of the water price increase argued on the basis of the facts i) that a new tax is never easy to implement (Tabichi, 2026), and ii) that such a tax could stifle urban development (Bardini et al, 2026 ; Money, 2026).

A special session was dedicated to recent improvements of SWTPs (Storm Water Treatment Plant). Chirac junior (2026) presented the new SWTP built in Paris by WWC. The peak capacity of this facility is 260 cubic metre per second and the main innovation consits in the fact that it is the Seine River itself that is treated below the most downstream CSO outfall in the city. This solution has proved to be more cost effective than rebuilding the entire sewer network of the city. WWC also presented its latest innovations in storm water treatment : latest improvement in lamellae settlers with chemical assistance (WWC, 2026a and 2026b), electrical trapping of ionised forms of metals (WWC, 2026c), and a new system of stormwater disinfection using ultraviolet lasers (2026d).

Bryan (2026) gave one of the most long awaited presentations. He presented the results of the long-term study, funded by WWC, on the restoration and recovery of the Blue Green River in Dream City. Dream City has been the first one, in 2006, to entrust the management of the whole urban water cycle to WWC. After twenty years of incessant and intelligent efforts, the quality of the Blue Green River has drastically improved. It is considered that 98% of the total area is now connected to the storm sewer system and treated by the SWTP. The mean pollutant removal rates (on a year basis) are about 99% for SS, 98% for BOD and COD, 95% for total nitrogen and phosphorus, and between 90 and 94% for metals, hydrocarbons and most of trace organic compounds. After treatment storm water is stored in a big reservoir, then pumped and distributed to 80 infiltration basins, most of them located in the upper part of the catchment, in order to refill the water table and to ensure a flow rate as constant as possible in the river. Now genetically modified brown trout and salmons can be caught in the city, and after a total removal of all the contaminated sediment (10 000 tonnes have been removed) and replacement by clean sand, children can play and swim in perfect water.

Yet some problems are remaining that must be overcome by further research. Bless and Luck (2026) presented the conclusions of the scientific evaluation of the LA accident. In 2024, during a severe storm rainfall, the electric power supply of the FRTC (Flood Real Time Control) system of Los Angeles failed. This resulted in the loss of human life (3500 people) and, above all, total damages costing 15 US$ billions. The conclusions of the experts are that energy management has probably become the weakest link of the flood control chain. During the discussion, it was suggested that WWC could take over the urban energy distribution, in order to improve its quality of service and security.

In some discussions, the problem of water management in developing countries has also been raised. Attendees were unanimous in congratulating WWC for having solved the problem of drinking water by distributing bottled drinking water, without any profit, in the whole world. Regarding stormwater management, the general opinion was that there were no good solutions as long as these countries were not financially *solvent. Akanabe (2026) (the only one representative from Africa) gave a paper trying to estimate the real human costs of the current inadequate management of stormwater. He suggested that, in the whole Africa, more than 50,000 people could have died from flooding and about 2,000,000 from diseases linked to water problems during the last year. Yet, without any official statistics, this information must be taken very cautiously.*

To finish I would like to thank the Word Water Company that sponsored this conference and allowed the organisers to invite all the participants free of charge.

Box 3 : A look back on 20 years of success – Some words from the chairman G. W. Richman on behalf of the opening ceremony of the 20th annual Worldwater shareholders meeting held at Mondsee, Austria, on March 29, 2027.

Dear friends, partners and fellow shareholders

Now – at the point of retirement and handing the company's leadership to the next generation - I would like to take this last opportunity not only to thank you for your unlimited help and support during the time of my chairmanship but also to reflect on the development of our company. Such reflections are made even more pleasant by the fact that the last 20 years at Worldwater have been a continuous story of success.

Looking back, we all remember that only about 2 billion people have been living in urban areas at the beginning of the new millennium. In the last 25 years this amount has doubled thus thankfully leading to a sharp increase in pressure on public water management. Parallel to this development also the reliance on the free market system in water management has become globally widespread. Starting with the richer northern countries, the ownership and service have been increasingly transferred from the public to the private sector. The driving force in this early stage of the development was the emphasis on pricing water at full service cost. This development has been greatly supported by the political pressure to accommodate a high standard level for water service. E.g. EU alone had to invest app. 20 billion Euro in the period 2000-2015 for compliance with the EU water framework directive – largely in the central and eastern European nations that joined EU in this period. Although first only some French and English companies engaged themselves in this market, the long-time economic potential soon became clear and we all remember that an increasing number of private sector companies began to compete.

In 2007 finally our company Worldwater emerged due to an enormous investment of Bill Gates, the oil industry together with the market leader Suez and Vivendi. It was due to the farsighted attitude of our first chairman B. Clinton that the US. Government (under the presidency of Hillary Clinton) engaged itself in the initial phase thus also establishing the everlasting connection between our company and the political leadership of the US. The Clintons argued convincingly that only the free market system could guarantee the enormous investments necessary for accommodating a high water service level in urban areas.

However, although Worldwater already at its start had a market share of about 50% it took another 11 years until – in 2018 – the last competitor, the European RWE, gave up and left the market to us. In the beginning of this economic battle water companies raised the funds needed for the establishment of the water infrastructure and operated the water services on a full cost recovery basis. However soon also a global problem began to emerge : companies invested willingly in the northern hemisphere as well as in emerging Asian and Latin American countries – in short - everywhere, where either people directly or by means of subsidies could afford to compensate for the enormous investment and maintenance cost. Urban agglomerations in poorer regions, especially in Africa, became increasingly decoupled from the development and suffered from insufficient water service levels.

Although Worldwater did see the danger and avoided such risky markets also other water companies flourished economically during that early period. In order to achieve a further market concentration Worldwater had no other choice than lowering the price of service: During 2015 to 2018 chairman G. W. Bush offered water service at zero level for all major industrialised countries. As we all remember our competitors could not cope with this market strategy and one by one had to give up.

Immediately after winning on the economic battlefield Worldwater went to court in order to fight the many legal restrictions that have been implemented by various government against unlimited raise of water service pricing. Luckily also this battle was fought successfully and by 2021 the golden period of our company started. You all remember that we started 6 years ago by asking for an equivalent of 20 % of the gross income of any inhabitant of the western hemisphere for a full water service and raised the fee annually ever since. But as I had to inform you also during our last annual shareholder meeting in Palm Springs, we have now reached the cost limit where people find themselves economically threatened. Industry began already to invest in recycling technologies and we face the situation that 10 years from now industry could cover a major amount of its demand by internal water reuse systems as well as by industry owned separate water service systems with demand tailored quality. And the high water price could lead to an equal increase in research and development for establishing water saving and alternative systems for single households.

But this development does not come as surprise and during the last year we began to counteract this threat against the economic development of our company. And reaching this point I now would like to reveal the reason for choosing this years venue location at an European inland lake: Some days ago we finally signed the legal papers that give us the sole and unlimited access to all European alpine water resources – and thus also to this beautiful lake. Don't be mistaken - this deal is not just another share in water infrastructure but opens a full new area of our company, where we now aim no longer for water infrastructure but for ownership of water itself. Although a long and harsh battle can be foreseen until Worldwater will dominate also the global water resources, I am convinced that we will achieve the goal and then reach – what future generation will probably call – the water age. . .

Box 4 : I thank Mary Ho-Chimin"s (President of the Advisory Committee of the New Water Foundation) kind invitation to present my personal view on the" last 50 years of Urban Water" and her permission to express it in the form of an open letter to my grandchildren, Manel and Mariana, two young engineers expecting to have their first job at one of the Centres of Excellence of the Aquaharmony network…

Lisboa, February. 2028

Dear Manel and Mariana,

It is not new for you that, since I was a child, younger than you are, I love hearing narratives from elderly people. Specially my grandparents" long and fascinating stories of real life, war and peace, health and death, sea and earth, love and hate, erudite music and circus … perhaps because they invariably ended with a word of trust, belief and expectation on human beings. Today, I realise how their attitude and wording may have influenced my own perspective of the world and my early feelings of being a "citizen of the world". Fortunately your parents could also hear and learn from my parents in a sound chain of passing the "heritage". But I also feel that past heritage can only become alive *when we adjoin the impulse and driver of making the future happen.*

You are young engineers in the water and eco-sanitation fields, as I was in the past, but you will face different challenges today and in next future. About 50 years are separating our professional activity and it looks quite clear, in my retrospective view, that the past 25 years were not so worldwide prosperous as we had foreseen in the beginning of this millennium…You will ask why? I would not feel comfortable in discussing or judging too much on the major causes and/or protagonists of failures. I would simply like to offer you, in short words, my personal view of the facts. Hopefully this will help you to build, with your own vision and in your own way, a new era progress, being water and nature more and more elements of peace, welfare and quality of life…

The year's 1977- 2001

When I finished my University degree in Civil Engineering Hydraulics Engineering, in 1977, I had the chance to become a junior research assistant at the Hydraulics Dept. of Laboratório Nacional de Engenharia Civil (LNEC) a well-recognised research institution. The "water and sanitation" were worldwide defined as a priority and forecasted as a major area of research and technological development.

My main scientific area of interest was, since the beginning, "urban drainage", a concept dealing almost strictly at that time with the conveyance of wastewater and stormwater in the cities mainly through buried sewers. We were still in a period when the solutions implemented were dominated by civil engineering viewpoints. Major challenges and improvements both in scientific knowledge and in institutional co-operation occurred in these more than two decades based on new understanding, new data, new tools, and new policies, supported on multidisciplinary know-how.

In a time where communications were not yet global, I had the privilege of travelling around the world, meet scientific and technical professionals, from America to Australia, and share ideas, projects, cultures, experiences and visions within the so called "urban drainage family". Born when video conferencing was not already a routine means of communication, and starting to work when travelling to meet someone for business reasons does not make sense any longer, it is difficult for you to understand what I mean. Bearing in mind that I had my first personal computer only ten years after my graduation and that internet and email became widespread only after mid nineties, please try and realise the enormous scientific, technical and personal value it was for me to be part of such "family".

In Portugal the professionals in the field (mainly engineers but also sociologists, economists, lawyers, etc), from academic and research, to consultancy, construction and municipal engineering had a lot of challenging business. Investments in the water sector, mainly from mid eighties to first mid decade of the 20´s were something close to 400 billion Euro or 350 billion US$ (prices referred to 2005). The capital funds coming from EU (Portugal was at that time a net receiver) associated with a water sector institutional re-organisation made possible a clear improvement in water and sewage infrastructures.

A quick evolution occurred from the earlier "urban drainage" (70´s) to "urban pollution management" (90´s) and to "sustainable water management" (by the turn of the millennium). Topics such as: more efficient use of water in all consumptive sectors, price at full costs water services, performance assessment and benchmarking and improving knowledge on ecosystems functions, were addressed as key major issues to mitigate, at a global level, the water crisis coming from increased consumption x increased population and continuous exhaustion of natural resources. At European level the "Water Framework Directive", approved in 2000, during the Portuguese presidency of EU, committed all EU member state countries (15 at the time) with targets related to the achievement of good "chemical" and "ecological" status of freshwater by 2020…

As far as scientific knowledge is concerned the following issues were considered to be subject of a "changing of paradigm" (As stated by Harremoes, INTERURBA II, Lisboa, 2001):

- Incertitude, risk and failures – we are still facing engineering surprises due to ignorance of basic phenomena, uncertainties unaccounted for and risks of technical failures (related in particular with uncertainty of predicted performance, lack of knowledge on the effects of chemicals used in society and lack of attention to the technical risk assessment versus risks associated rain-runoff);

- Ecology of receiving waters – prediction of ecological effects of urban drainage is not possible by modelling, because lack of knowledge on the cause-effects relationships (the policy as to based on empirical –iterative approach, but it as to be followed by dedicated monitoring and analysis).

- Decentralised techniques – an option regarding "sustainability", requiring however good and sound professional analysis and designs in order not to make new mistakes based on new uncertainties.

It became clear that "urban drainage" was a concept too narrow to cope with further developments and new paradigms. Social, institutional and economic aspects began to play an important role in the all picture. A very interesting and challenging task for engineers – to face the need of wide their traditional area of interest.

The years 2002 - 2027

…The beginning of the new millennium shows a lot of black spots and weaknesses of political, geo-strategic and socio-economics balance forces worldwide. Political and religion fundamentalism lead to frightening and terrible uncertainties in society.

Sophisticated terrorist attacks affected main centralised water infrastructures in large cities making millions of victims, both directly and indirectly. May be you have heard (my friends Prof. W. Pound and Prof. Chocolate reported it) of the flooding of the London underground after a collapsing trunk sewer, the trapped and killed people in the Berlin Convention Centre for same reason, the poisoning of the western Paris water supply, the bombing and collapse of the electrical power in Buenos Aires and Los Angeles.

Southern Europe, including Portugal and Spain (hopefully the Bask movements were not inspired by evil ideas of terrorism, on the contrary they slowed down their activities) were not so directly touched by these kinds of tragedies and disasters. The main problems however remain on very poor standard related both to "Operation & maintenance" and "preventive rehabilitation" activities and a clear degradation of valuable infrastructure assets occurs, as a consequence. All our investment on early 20´s in R&D related to this topic was just forgotten. This situation was aggravated by a migration of good technical staff to the new EU European eastern countries where a potential for capital investment was granted.

Years of global world recession in economy lead to a situation in which: European research and structural funds, namely for the water & environment sector, slow down substantially after 2006; World donations and funds to poor and developing countries reduces to a minimum level just addressing the most severe survival needs.

On the contrary as it would have been expected, I guess, some years earlier, this situation lead to a point where developing countries, namely in Asia and in western Africa (in this case I know a little bit better) had to decide, promote, develop and finance mainly by themselves. Surprisingly for me, who had in the 90´s a sceptical view on the development of Africa, we could perceive and follow an interesting, step by step, grow up of human capacity building, an increased wish of co-operation between neighbour countries sharing international water basins and a clear strength of dialogue at political level. In such countries the decentralised techniques had a significant potential for use. Moreover no barriers were made by external agents selling the well-established techniques of large networks and treatment facilities.

The belief on keeping this "dream" alive and make it the origin of a sound "new world water paradigm" touched Bill Gates who proved (surprisingly for some!!) to be a real philanthropic, by establishing the New Water Foundation. The initial success of Foundation (as well reported by his President Dato Jodrey Paranumba, a good friend of my colleague R. Ashley) was to establish a number of Centres of Excellence to develop a new generation of experts in what we call now, as you know, Profession of Aquaharmony. The initial Centres were located in USA, Sweden, Japan, China and South Africa (countries where according to Bill water advisers opportunities to radically change thinking were considered more likely).

You probably remember that, in the years 2008-2012, LNEC got from the Foundation a special contract aiming at co-operation in the "spirit of the new profession" in Mozambique, South of China and East Timor. You have been with me for some holidays, in Macao, Maputo, and Dili (remember?), and I wonder if this experience was not a motivation for your professional choice…. From now, my beloved children, what is relevant is the future that is in your hands…

By the way and regarding the future I heard that your mother is making some prospective exercise for the next 25-30 years… it is certain that the future is never what we have forecasted but it is also sure that it will be worst if we do not dare to anticipate scenarios, to have our visions and to discuss the changing of paradigms…

In a prospective we do not plan the future but we do plan for the future, because this, I believe, will be more and more uncertain and unpredictable….

Box 5

Dato Jodrey Paranumba - *President of the New Water Foundation*

Extract from an Inaugural speech : 20/21 Vision : the next 30 years in urban water

Dear colleagues,

When I look forward to the next 30 years, I find myself reflecting on the past 20 years. We of the Foundation have the mission to continue the wonderful work that our predecessors started in 2001, being empowered to intervene anywhere in the world to ensure equitability of water access. Today, of the world"s population of 9 million, there is not a single one of them who does not have access to safe water and effective sanitation ; a remarkable achievement in such a short time. How did we achieve this miracle? And can we sustain it for the next 30 years?

In the year 2000 "World Water Vision" was published. This remarkable document contained scenarios for the year 2025, which were in many respects, prescient. I will not, however, dwell on this vision, as you know it well. I will instead look at the origins of change and highlight some of the differences in implementation from the "Vision" and try to project forward into the next 25 – 30 years.

In my view, the start of change began with the escalation in conflicts at the start of the Century. Despite the ascendancy of the capitalist world-view, these conflicts illustrated the need for the implementation of capitalism to be tempered with a softer touch, particularly where key human rights were concerned. The acknowledgement at all levels that access to water and sanitation were fundamental rights and a cornerstone of equity, was a major breakthrough. The developed (in the main, northern) countries realised that without equitable access to such rights, the rest of the world had little to lose in any conflict, and the emergence of weapons of mass destruction held by many disparate groups only added to this threat. Thus the driver for change was primarily one of risk management, rather than any altruistic or "fellow-man" ideal. We became quite good at evaluating and minimising risk.

Although the risk of conflicts appears to have been the primary driver in effecting change, a social factor, there were also many other threats at the time, both environmental and economic. Chief amongst these were the effects of climate change on the world"s water systems, a further skewing of water availability through precipitation from the south to the north, coupled with rises in sea level of the order of centimetres.

As we now know, the worst projections were unfounded, and so far we can detect some 3% increase in precipitation in the northern hemisphere, with more surface water and rising groundwater levels, and a 10cm rise in mean sea levels. Of course, the storms are more severe, and all of these factors taken together, mean we now pay relatively some 50% more in our insurance premiums than in 2001. This is despite managing our surplus surface and groundwater rather better than we did then, with the emphasis on "near-source" systems.

In the developing world, changes were not so easily managed. You will recall that at the start of the century, despite billions of Euros being spent in the previous decades on infrastructure by world-wide organisations, there were nearly 2 billion without safe water and 3 billion without effective sanitation, and millions were dying from associated diseases every year. This could only get worse as the population continued to grow by some 100,000 a year. The climate change effects exacerbated these problems with even less rainfall. For example, in the past 20 years, there has been a reduction of 10% in the total rainfall for the whole African continent. In most countries on that continent, and in much of Asia, the growing use of the existing limited water resources as carriers of waste, in emulation of the "best" developed world practices, indicated that the majority of the world"s water would be so used by the year 2010.

Whilst not wishing to sanctify Bill Gates our founder, his philanthropy in establishing the New Water Foundation in 2004, probably prevented the destruction of mankind as water became the key resource in the second quarter of the 21st Century. Our initial mission was to find a way to genuinely bridge the gap between the various professional experts who would be needed to develop the new world water paradigm. Unfortunately, the developed world"s way of educating its" professionals was based on the Greco-Roman model as exemplified by the Descartes reductionist approach - a scientific world view. This led to compartmentalisation, a concept we find difficult to understand today, as we have learnt to take a wider view, more commensurate with the ancient Chinese philosophers. This of course, has been fused with the Greek capabilities in logic, to create a new philosophy, which our Founder called "a synergy between the East and West". In the early 20th Century there were a few advocates of changing world views – Koestler, Pirsig, Capra, and others and the new knowledge emerging in physics did challenge entrenched old world views. At the time, though, most "hard" scientists took little regard for the "softer" sciences, and arts were generally considered a secondary, or inferior factor when it came to anything to do with water. Although some praised the inherent aesthetic value of water, but could not measure it despite trying hard. Our initial success was in the establishment of a number of Centres of Excellence to develop a new generation of experts in what we now know as the Profession of Aquaharmony.

Initially Aquaharmony Centres were set up in the USA, Sweden, Japan, China and South Africa, as it was in these countries that the opportunities to radically change thinking were considered more likely. The essence of the early work in the Centres was to utilise the natural earth systems as far as practicable, with a counterpoint of "hard" technology where this was required. When we dealt with the earth"s natural systems this also included the people. Our programmes of work have had to convince all of the actors in the water cycle to treat water systems with respect. This meant that whilst expectations of clean water and adequate sanitation were justifiable, and ultimately realised, these expectations came at a price. This price included behavioural as well as a financial cost. It was in the demonstration of the reality of these costs to the developed world that we had a first major breakthrough. We were able to demonstrate that people"s use of water in the developed world was literally "costing the earth", with consumers (I will not *use the word* customers*), paying on average only some one third of the true economic costs of water services. The wish to be able to use wholesome water for a range of domestic purposes such as car washing (you remember them?), a trivial and pointless activity, was deeply ingrained. In hindsight, such activities, unforeseen consequences of the construction of the vast water service infrastructure for public health maintenance by our Victorian forebears, now seem stupid.*

Ironically, without the vast inherited water service infrastructure from the 19th Century, our 20th Century urban consumers could not have afforded the water services they enjoyed. As to reconstruct these lavish systems would have required taxation levels set at some 50% of incomes. Consumers at the time were not even willing to pay for the costs of maintaining their inherited water service assets, and service providers struggled to maintain services at the profligate use levels which people expected as right.

We got the message out to the developed world by using all forms of media at our disposal. 2D Television was of course still with us then as a passive pastime. Nonetheless it was the best means of mass communication at the time. We infiltrated the school curriculum with the best technological multi-media equipment being provided for virtually every schoolchild, with built-in Aquaworlds, the compulsory web server system. It was very difficult at the time to establish a continuously evolving system that prevented the user getting bored, but we managed it. Now nearly 20 years on, we have a new generation of people who have all been exposed to these various inducements to respect water systems. This has led to a new paradigm of expectations in the developed world. Significantly, there is now no expectation that the direct costs of water services to the consumer should reduce year on year, at the same time as an improvement in service provision.

You will recall that in some countries, particularly those with a private water service, the water service industries were heavily regulated and were not allowed to pass on the real costs of water services to domestic consumers. Curiously, this was not the case with industry, where full costs were expected to be passed on, under the "polluter pays" principle. Of course, regulation at the time did not recognise the full economic cost of water service provision, neglecting to account properly for the external and whole life costs, as the regulators were only concerned with short-term goals, and what the consumer paid at point of delivery. In fact, as we showed, the consumer was in effect paying considerably more in the world-wide degradation of water resources and the damage caused by the energy supply systems needed to maintain water services, feeding back into climate change problems. This was another key element in the message we got across.

So now we have water service provision in the developed world that is as much in harmony with the natural cycles as it has been possible for us to achieve. Where we need to have technological interventions, due for example to localised water shortages, these are also as low technology as we can make them and utilise near-site opportunities for recycle and re-use. Fortunately, our pioneering work was in time to prevent the worst excesses of developed world technologies being globally applied. The world water shares *which we launched in 2006, whereby everyone working was automatically included in a compulsory subscription to "world water capital", provided the finance to ensure that there was water for all, rather than some. People were generally prepared to pay this small tax as they knew precisely where it was going. The benefits, as stated at the outset of this talk, have been less global conflicts as a result of a greater world-wide sense of harmony, a small price to pay to reduce risks for the richer nations.*

Let me now turn to the future……………….. . ?